IN

Morphological Variations across Disciplines

Variaciones morfológicas entre disciplinas

investigación
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Abstract
The paper explores design methodologies that deepen the relationship between form and environment in the academic context of Parametric and Generative Design, an elective course open to undergraduate architecture and industrial design students at the National Autonomous University of Mexico. The paper presents student work and design processes that exploit formal mutability, build bridges between disciplines and construct a transferable body of research.
Keywords: parametric design, systems thinking, interdisciplinarity

Resumen
El artículo explora metodologías de diseño que estrechan la relación entre la forma y su entorno en el contexto académico de la materia optativa Parametric and Generative Design, abierta a estudiantes de arquitectura y diseño industrial de la Universidad Nacional Autónoma de México. Se exponen algunos ejemplos del trabajo realizado por estudiantes, los cuales anteponen la mutabilidad formal en procesos de diseño, interrelacionan disciplinas y construyen un cuerpo de investigación transferible.
Palabras clave: diseño paramétrico, pensamiento sistémico, interdisciplinariedad

The COVID-19 pandemic has exposed the profound interconnectivity between humans and the environment, challenging established design processes and broadening the spectrum that we must address as designers. The 2017 curriculum for the School of Architecture at the National Autonomous University of Mexico (UNAM) proposes a systemic approach that rethinks design's relationship to context, marking an important turning point in the discipline.[1] According to the architect and theorist Christopher Alexander, a systemic approach in architecture refers to the indivisibility of a design problem into subproblems resolved in a linear fashion.[2] Design thus shifts away from representing isolated elements in favor of orchestrating dynamic interactions between parts. This framework asserts design as a mediator between interdependent processes, an extension of its material and immaterial context.

Given the increased complexity of this approach, it is paramount to accompany this paradigm shift with new tools and processes. Computation in architecture harnesses the computer's enormous capacity for processing information through algorithmic design processes.[3] It distinguishes itself from the computerization of architecture, which refers to the use of a computer as a virtual drawing board

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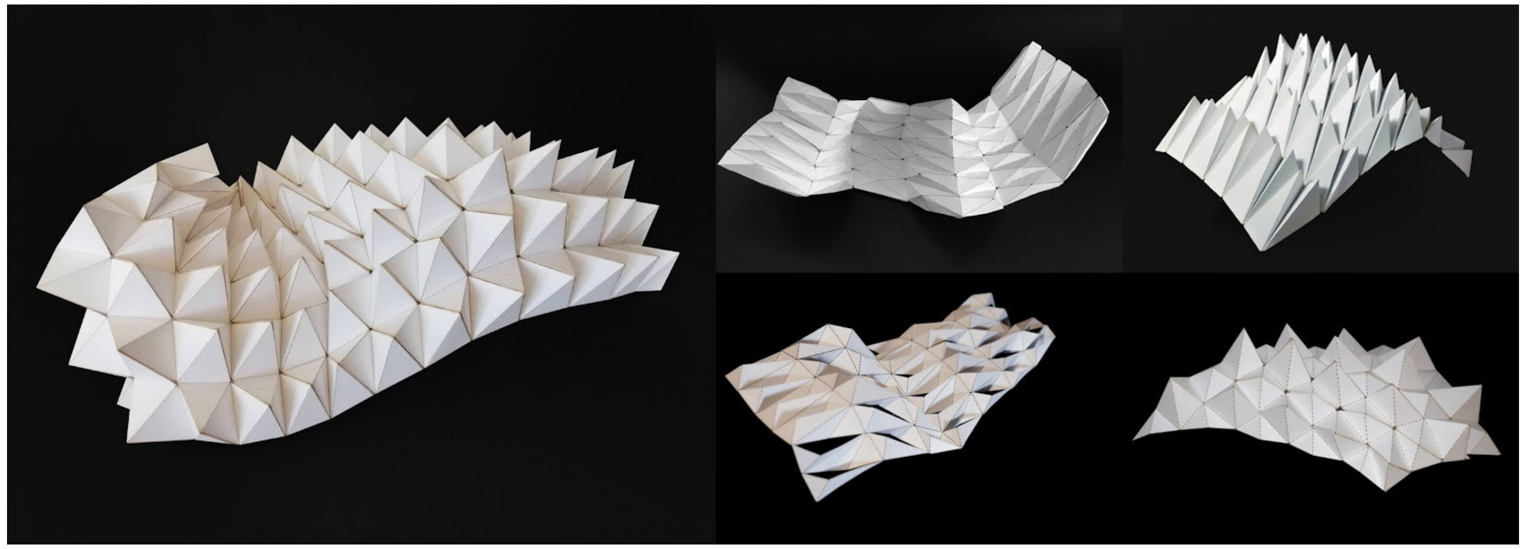


Folded surface mutations based on a generic algorithm. Formal diagrams developed by Daniela Solis, Sara Santana, Patricia Castillo, Vanessa Sánchez, Enrique Hernández and Rodrigo Rojas

to extend and accelerate established modes of design and representation. Computation, in contrast, permits an improvement in the designer's abilities, elevating their capacity to address highly complex, dynamic and multiscalar problems.[4] It is this mindset with which the elective course Parametric and Generative Design critically questions conceptions, tools and design processes.[5]

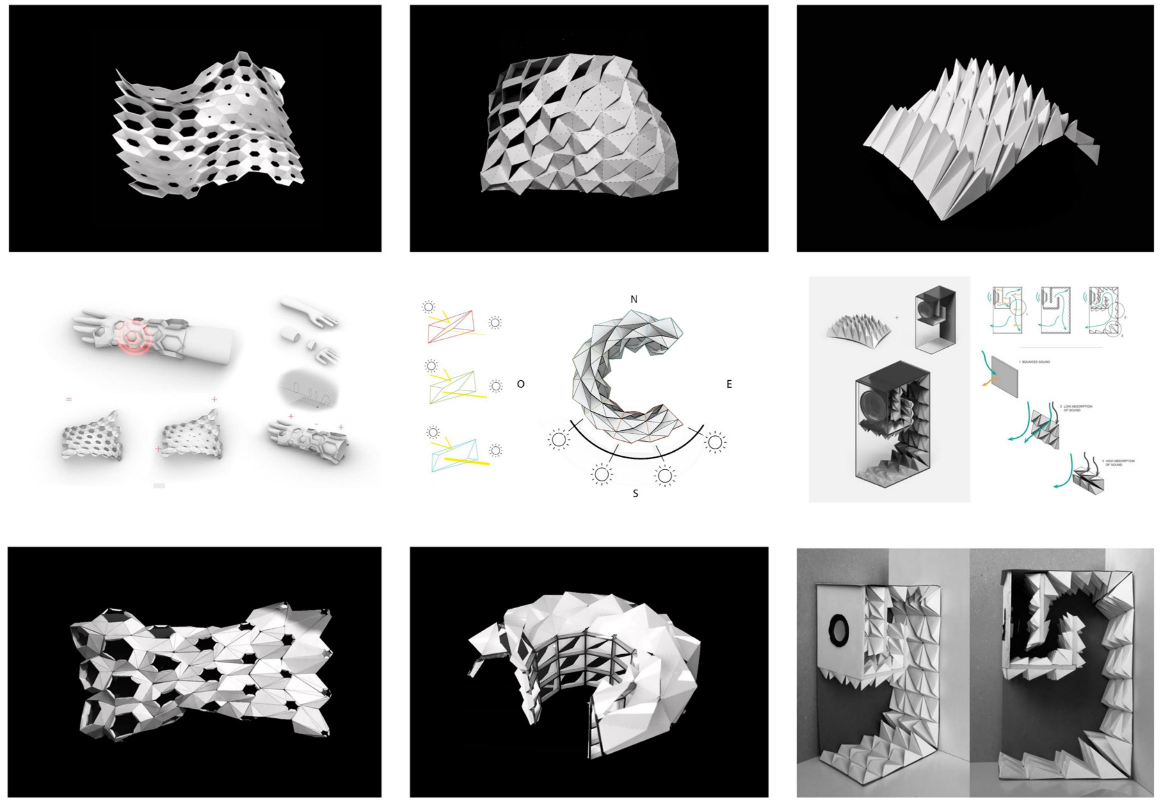
Parametric and Generative Design brings together architecture and industrial design students from UNAM's School of Architecture for four hours a week to explore parametric design processes and digital fabrication.[6] Elective courses are offered halfway through the degree, fostering a rich exchange of ideas and experiences between students of different years and, in the case of Parametric and Generative Design, between different design disciplines.[7] The following themes are examined in the course with the objective of applying systems thinking through parametric design:

1. Formal mutability as a mediator of forces and phenomena
2. Fluid exchange of parametric concepts between disciplines
3. Transferability of code and the construction of a body of design research

The images and examples discussed in this article are based on student work since 2019, the year in which this elective course was first given in its interdisciplinary model. These design processes and products illustrate the methodologies and questions investigated in relation to systems thinking.

Formal Mutability

The crisis that brought computer-aided design (CAD) into the architect's toolbox can be traced back to the recession of the late seventies and early eighties. Faithful to the tradition of borrowing knowledge and methods from other disciplines in order to advance the discourse, experimental architects looked to the automobile, aeronautical and shipbuilding industries, which had been using CAD in design and production processes for decades. The complex forms that emerged from the use of these tools demonstrated a dynamic collaboration between the form and its active context.[8] This vision nurtured a theoretical discourse that guided the incorporation of CAD into architectural practice and influenced the development of the parametric tools used today.



From formal diagram to design concept at the architectural or product design scale. Student work by Paola Ruiz, Alejandra Rivera, Vanessa Sánchez, Patricia Castillo, Enrique Hernández, Rodrigo Rojas and Daniela Solís

Parametric design represents and interrelates forms and forces through the definition of associated geometric and mathematical rules.[9] These definitions can be easily edited and visualized in real time, allowing for a flexible design process. Explicitly designing and encapsulating connections between form and environment in a generative code requires an equally-sophisticated understanding of both geometric generation and external constraints.

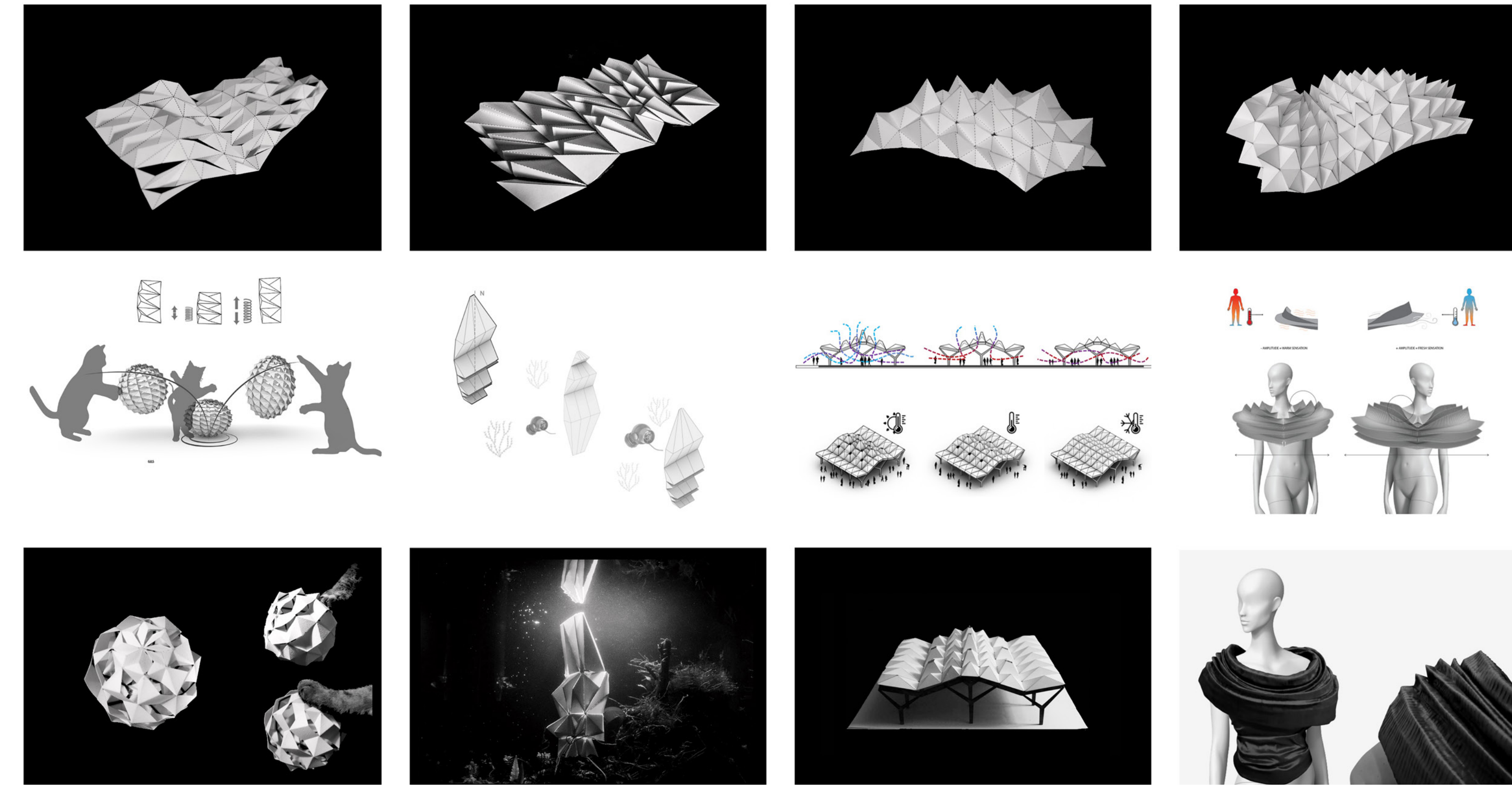
Parametric and Generative Design starts off by testing the algorithm's potential for generating a fluid world of infinite solutions. The first exercise opens with a generic algorithm, a simple pyramid tessellation created by subdividing a surface and displacing the centroids of each cell; each student must disrupt the original definition and create a new variant. Some students opt for increasing the number of subdivisions, creating apertures in the folded surface, changing the proportion of the cells or varying the heights of the folds. Exploring the mutations of a shared code encourages a better understanding of geometric rules, an essential skill for designing one's own algorithms in the future.

These virtual diagrams are materialized in order to conduct a multisensorial exploration and discover the form's potential. Inverting the traditional process of finding a formal solution to a problem immerses students in a steep learning curve. We offer a short-term objective that helps distract them from the overwhelming challenge of learning a new methodology, a new software and an alternative design philosophy all at once. The parametric production of fabrication files facilitates the manufacturing of prototypes at different points of the process, increasing the number of iterations of the design and intensifying the quality of feedback, with digital and manual investigation complementing each other. After surviving the whirlwind of frustrations inherent to the construction of a complex surface, the students wake up to a surprising assortment of peculiar forms. They take the models in their hands and get a feel for their texture, rigidity, smoothness, flexibility, transparency, opacity, etc.; they fold them, stretch them out and test their resistance; at times, a model falls apart, but in the process, students approach a form to see it for what it is, not for what it does.

Revisiting form through the rules of its generation (the algorithm) and the effects produced once materialized (the physical model) helps undo preconceived notions about function and its formal expression. Identifying unique formal characteristics as direct outcomes of virtual and physical generation situates the designer at a vantage point from which they can imagine possible interactions between form and external parameters such as water, wind, friction and light, among others. Form can resist, conduct, capture, transmit; form is not passive and should inform design processes from their conception. Understanding the potential and mutability of form through its parameters empowers the designer to participate in broader systemic processes.

Interdisciplinary Exchange

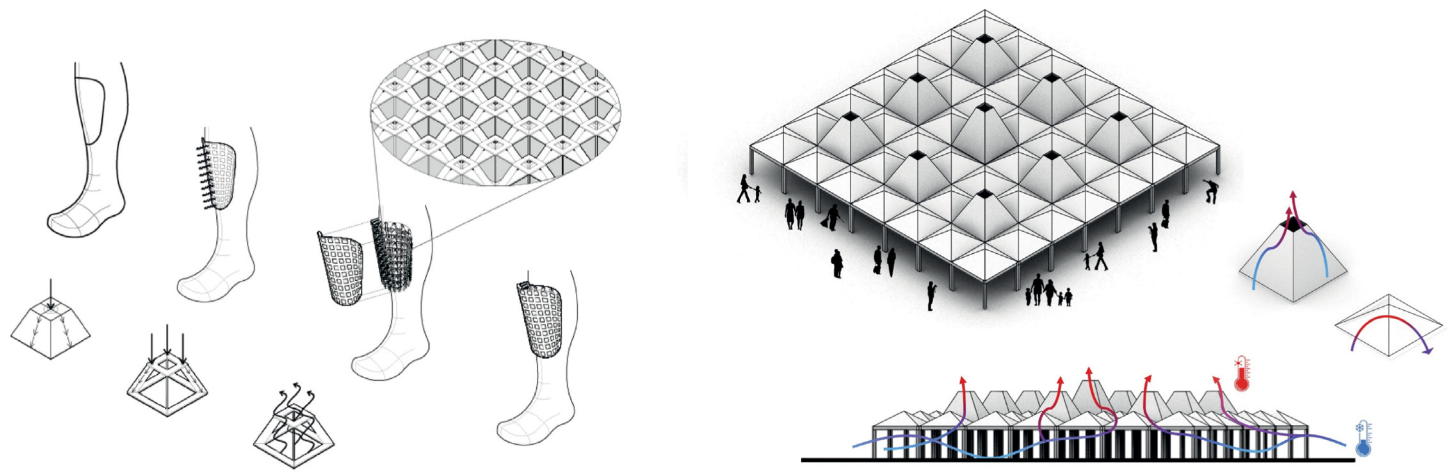
Using systems thinking as the operative framework for design produces an indispensable interdisciplinary exchange that brings together design professions responsible for creating objects and experiences on a wide spectrum of scales. Although the specialization of processes can catalyze important advances in all areas of study, an undesired consequence is the emergence of isolated fields of knowledge that, at times, increase the complexity of attaining a design objective. Parametric design is a means for bridging the gap between a variety of disciplines. This methodology helps locate concomitant answers to different problems through the aforementioned spectrum of scales.[10]



As a continuation of the first exercise in which the students imagine their form negotiating different external parameters, a function is assigned to the form at the architectural or product design scale. From the same seed of code emerge proposals that cover a wide range of applications: a roof structure, a speaker, a green wall, a garment, etc. However, it would be shortsighted to assign these proposals to pre-established product categories; the design proposals, having been explicitly conceived in relation to a dynamic parameter, test limits and propose new applications at the intersection between disciplines.

Novel reflections on temporality, adaptability and kineticism inevitably arise from this process. For example, a surface composed of semi-open hexagons offering a range of flexibility and rigidity is translated into a wrist orthosis adaptable to different users, degrees of injury and phases of recovery. A student proposes an interchangeable modulation and an open-source code; dynamic attributes born directly from the formal exploration that perhaps would have remained out of reach if they had simply begun with the task of designing a wrist orthosis. In another case, a student observes that their model, born from an algorithm for subdividing pyramids, creates a ripple effect between surfaces, which leads them to contemplate the potential of harvesting energy through a series of piezoelectric cells. The prototype migrates to the bottom of a fish tank, where its movement is tested in response to water currents. The simulation provides valuable feedback for redesigning the joints and increasing the mobility of the cells and their subsequent impact.

In yet another example, we can observe how the same code, manipulated by two different designers, has inspired designs that diverge in scale and primary function but coincide in favoring the same external parameter: interior ventilation. At the architectural scale, the roof structure directs hot air toward its center in order to evacuate it through convection and avoid contending with the entrance of cold air along its perimeter. The height of the cooling towers grows in direct proportion to the concentration of hot air, forming a rigid structure as a secondary outcome. At the product design scale of a shin guard, the most important task is to protect the limb from impact. The designer generates a shield that, in addition to blocking a blow, dissipates the resulting energy through its joints. The porosity of these cells allows the athlete to comfortably perspire during physical activity. The study and approach to parameters becomes a commonality between design processes and opens up opportunities for dialogue between disciplines.



Interior ventilation as common denominator. Work by Miguel Moreno and Rodrigo Rojas

As the final step to this exercise, the formal parameters undergo yet another revision in order to improve the proposed system; the next level of development takes into consideration structure and materiality. The process of continuing to define the design fosters dialogue between industrial design and architecture students, as some have decided to develop prototypes outside their own disciplines and therefore benefit from the expertise and wisdom of their classmates. The feedback loops that nurture a single project contribute to the cross-fertilization of ideas in the entire group; by the end of the semester, the resulting body of work sparks discussions that prompt new directions for the elective.

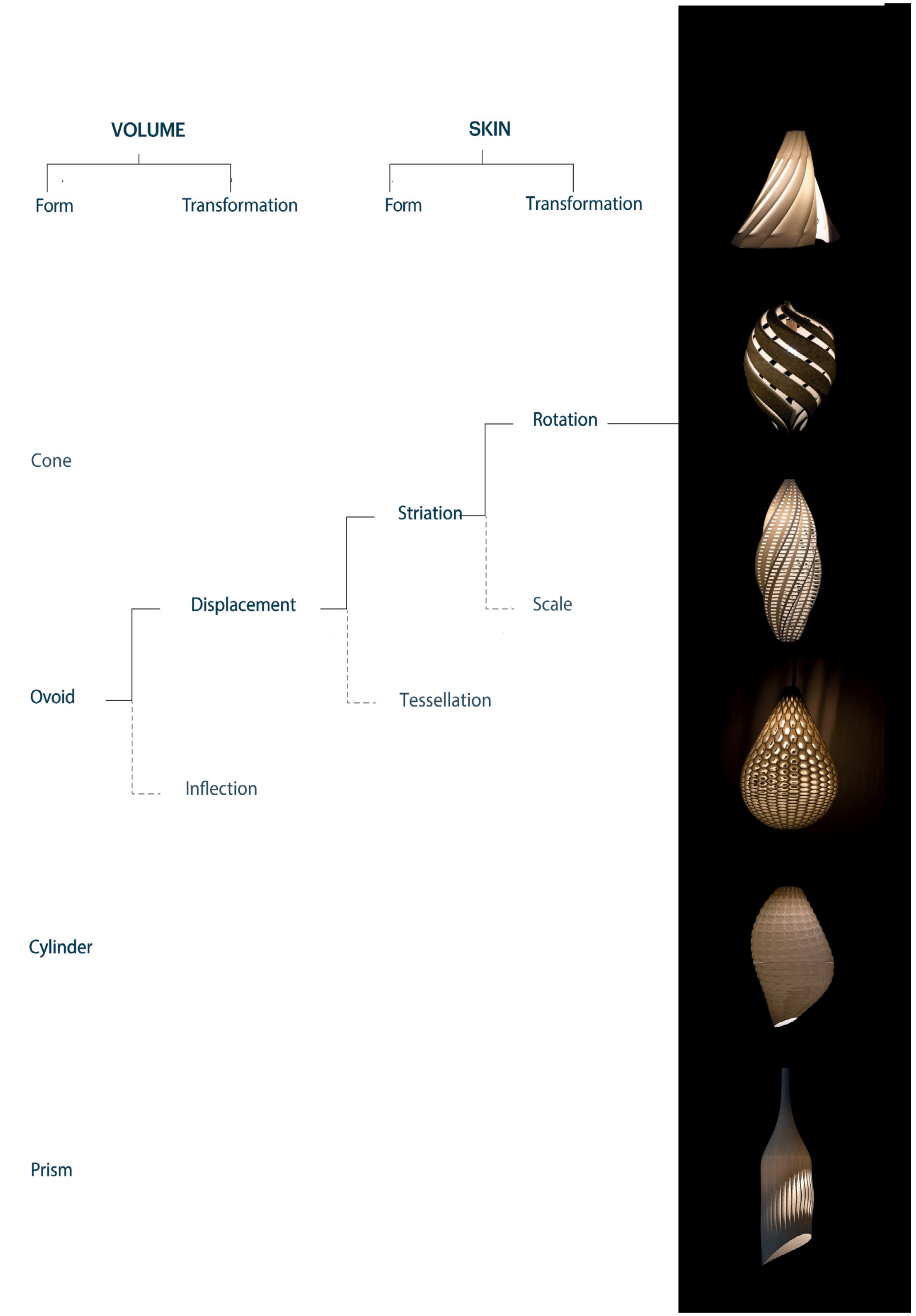
Constructing a Body of Research

Although the set of results seems incredibly complex at first glance, natural selection is an essentially binary process that unfolds across generations. Each time a living being reproduces, it doesn't begin from scratch; an inherited genetic code informs its creation and allows for the testing of mutations that persist depending on the reproduction of the code. This formula elaborates an exponential number of specimens that emerge from the same lines of research.

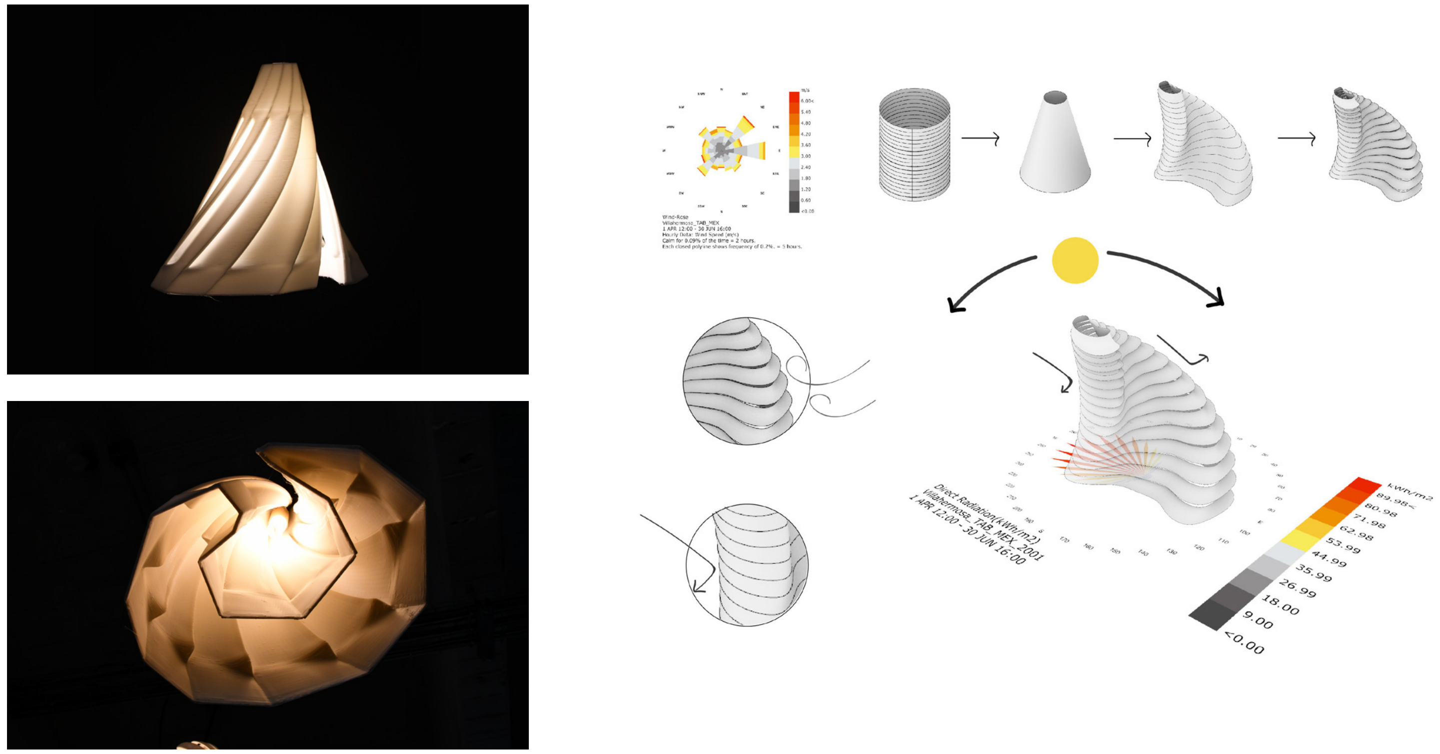
Applying this logic to the second design exercise of the semester, we investigate form as a mediator of artificial light, resulting in a family of light fixtures. The focus of this exercise steps away from the design of single, isolated entities in favor of the design of formation processes. After analyzing codes created by students from previous years, classification systems are proposed for mapping the shared DNA between light fixtures. These genetic trees serve as design tools, facilitating the connection between knowledge, the detection of areas of opportunity and the continuation of certain generation processes. Hypotheses are formulated in relation to the lighting and shading effects that will result from new parametric combinations; the ground zero for the generation of new light fixtures.

Formal variations in nature are the direct result of external parameters that demand adaptation. In the last exercise of the semester, we shift to the architectural scale and reinterpret the definitions used for light fixtures as precursors to bioclimatic buildings. Climate data sets compiled for a specific site are systematically visualized and analyzed and periods of critical analysis are defined to better understand the design problem.[11] Based on this understanding, we question how relationships can be established between the formal parameters that were explored in the generation of the light fixtures.

The definition of one student's light fixture, for example, might permit diffuse light to pass through a series of vertical slits that spiral within the interior of a truncated cone, obfuscating a direct view of the light source. Translating this definition to the architectural scale for the exploration of bioclimatic strategies, the student chooses a site and defines the design problem: How should one cool the interior of a tower during the hottest and most humid months in Villahermosa, Tabasco? Direct solar radiation and prevailing winds are observed in the critical period between April and June. The student transforms their definition to create a spiraling tower composed of horizontal louvers that fan out in the direction of the



A generative classification system that proposes two blocks of code for determining overall shape and skin treatment. Possible bifurcations and areas of opportunity emerge for investigating different species. Light fixture designs: Víctor Márquez, Ixchel Barreiro, Alejandro Arenas, Brenda Carrizales and Fernando Miguel. 3D Printing: Postgraduate Program in Industrial Design, UNAM. Photography: Tania Vázquez



The same parametric definition expressed as a light fixture and transformed into a bioclimatic building for Villahermosa, Tabasco. Produced by Ixchel Barreiro Reyes. Photography: Tania Vázquez and Rafael Carlos Guerrero

prevailing winds while maintaining a slender, closed facade in the direction of the highest levels of solar radiation.

Consolidating rules and relationships between variables in code produces a wealth of transferable information within a discipline and between disciplines. Parametric design contributes to the construction of a bank of definitions for climatic strategies adaptable to different locations and uses. The definition conjugates a clear relationship between form and environment that is capable of morphological variation, depending on the climate data of different sites. A shared language can also transcend disciplinary boundaries, allowing formal strategies to be reinterpreted at different scales and contexts. The design exercise becomes an interdisciplinary group effort that unfolds over time and space.

Closing the Gap

As professionals and educators, we continuously question our modes of thinking, teaching, designing and building. Are we preparing our students to tackle highly complex problems, making ample use of the new tools within our reach? How do we teach interdisciplinary workflows that spearhead important transformations in our field? There is currently a disconnect between the paradigm shift that is shaping the curriculum of the UNAM's School of Architecture and the design and fabrication processes that are taught in the virtual classroom. Beyond its visual appeal, parametric design can be the vehicle for implementing systems thinking in design. It is important to include parametric tools at every stage of a designer's education to nurture professional development and avoid deficient conceptual development. Literacy in form generation and information management is of the utmost importance for implementing meaningful changes between iterations; this simplifies the process of evaluating the product's success and facilitates feedback. We have illustrated several methodologies and results that take advantage of parametric tools for this purpose.

The relationship between parametric design and interdisciplinarity is not limited to facilitating interactions between design professions. This methodology can serve as a node for data and experiences to be handled with code. These tools can improve access to new inputs and facilitate collaborations in the processes that generate the objects we use and the spaces we inhabit, strengthening the relationship between design and context.

Notes

1. Systems thinking is part of General Systems Theory, developed by Ludwig von Bertalanffy in the 1960s.
2. Cristopher Alexander, "Systems Generating Systems," *Architectural Digest* 38 (December 1968), 605.
3. An algorithm refers to a set of procedures consisting of a finite number of rules, which define a succession of operations to solve a given problem. Achim Menges and Sean Ahlquist, *Computational Design Thinking: Architectural Design* (Chichester: John Wiley and Sons, 2011), 11.
4. Achim Menges and Sean Ahlquist, *Computational Design Thinking: Architectural Design.*
5. The elective Parametric and Generative Design is designed and taught by Professor Marcela Delgado Velasco with the assistance of Javier Mercado, a collaborator since 2019 and a former student of the course.
6. In the School of Architecture's curriculum, electives are organized under Lines of Professional Interest (LIP) with the purpose of channeling and strengthening the students' vocations. Parametric and Generative Design falls under the Design Process LIP.
7. In this course, we use Grasshopper, a visual programming language that runs with Rhinoceros 3D computer-aided design software. Digital fabrication processes include laser cutting and 3D printing.
8. Greg Lynn, *Animate Form* (New York: Princeton Architectural Press, 1999).
9. Robert Woodbury, *Elements of Parametric Design* (Abingdon: Routledge, 2010).
10. Kasper Sánchez, *Architectural System Structures: Integrating Design Complexity in Industrialised Construction* (Hoboken: Taylor and Francis, 2014).
11. We use Ladybug, an open-source plugin that allows us to easily import, visualize and analyze climate data with Grasshopper.

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